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G4V
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(54) **Coin discrimination apparatus**

(57) A multicoin tester has a coin inlet path 1 along which coins under test run edgwise past coils 2, 3 on opposite sides of the path, and through the windings of a coil 4. Electronic circuitry responsive to the inductive coupling of the coin with the coils operates a gate 5 to either reject the coin onto path 1b or to accept the coin into path 1a. Each of the coils 2, 3 and 4 is arranged in a parallel L–C resonant circuit 10, 11, 12 connected in the feedback path of an amplifier A1, the resonant circuit being energise sequentially by multiplexer M1. Each of the circuits 10, 11 and 12 has its own natural resonant frequency and is driven by a voltage controlled oscillator VCO. A phase locked loop including a phase comparator PS1 drives the oscillator VCO at a frequency corresponding to the natural resonant frequency of whichever of the circuits 10, 11 and 12 is connected thereto. As a coin passes say the coil 2, the resonant frequency of circuit 10 is modified by the coin and the phase locked loop changes the frequency of the VCO to maintain resonance. The resulting output at 15 varies both in amplitude and frequency. The amplitude deviation is digitised by an analogue to digital coverter ADC and compared by a microprocessor MPU with stored values in an EEPROM to determine coin acceptability and denomination; so as to operate gate 5.
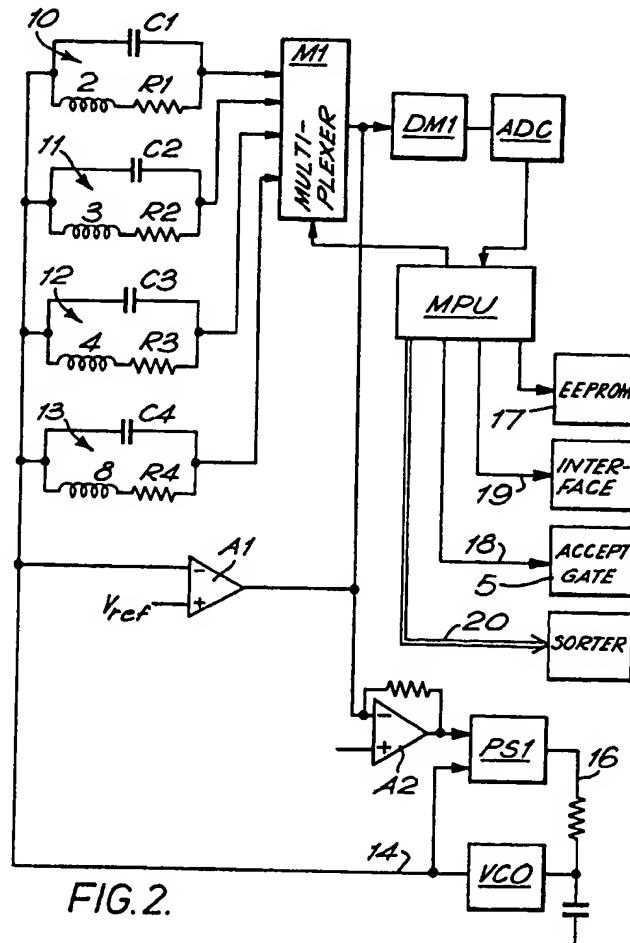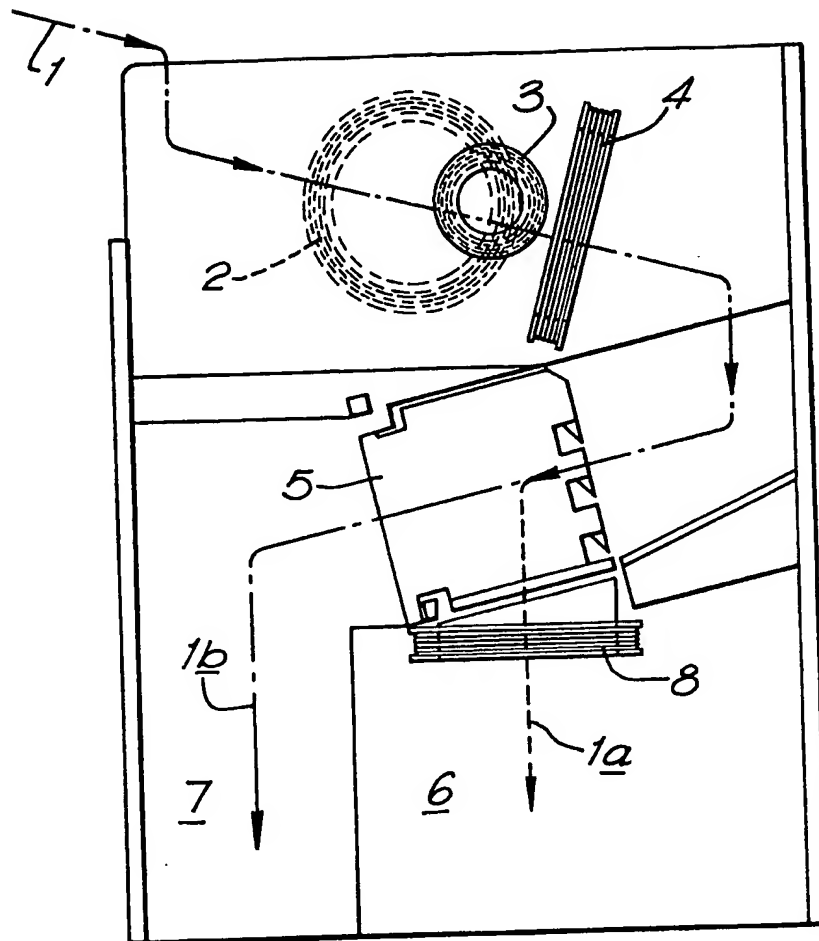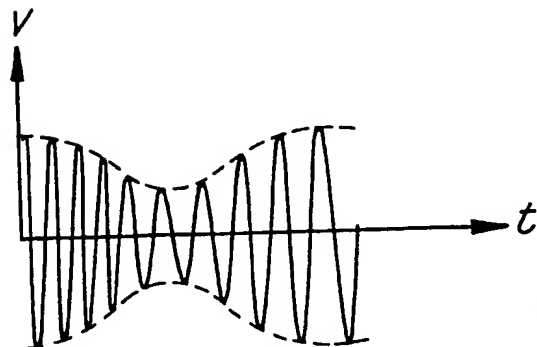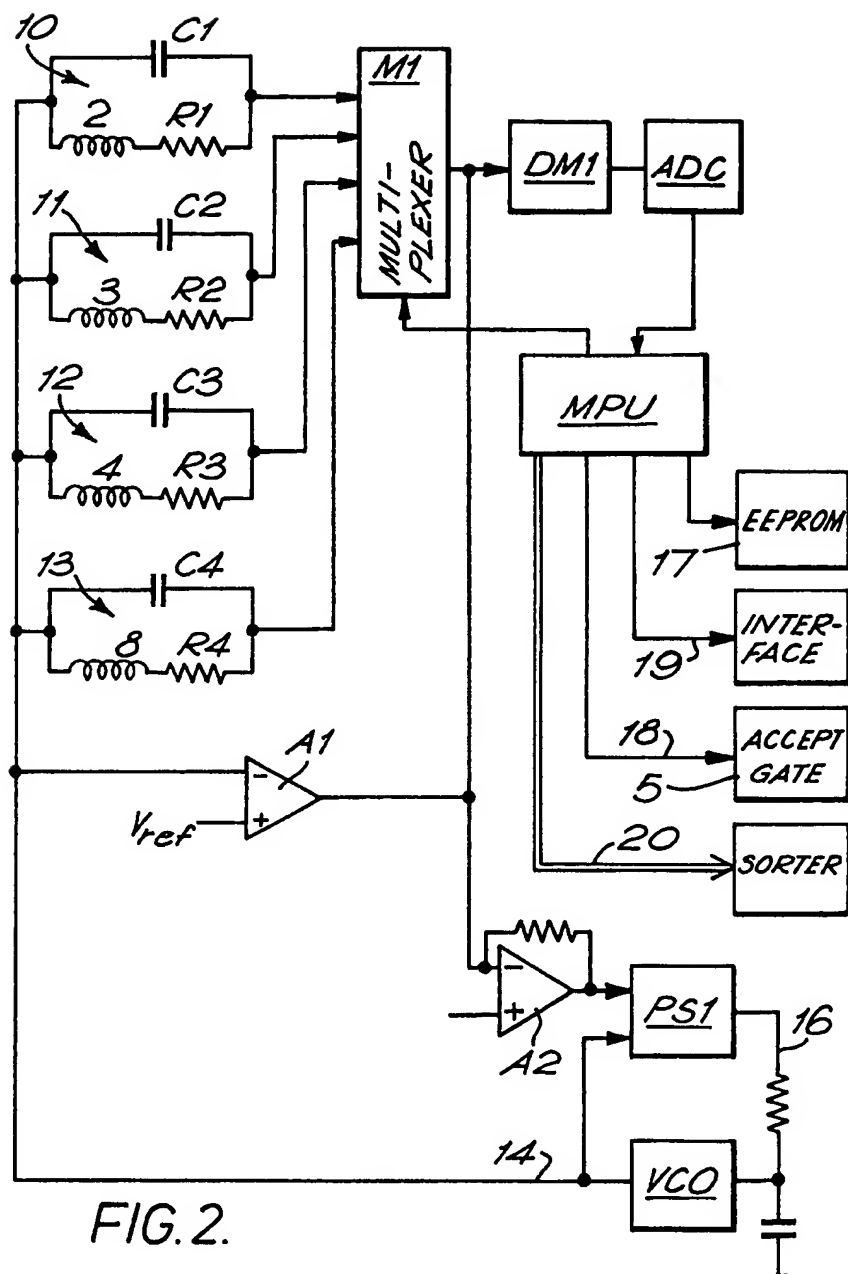

FIG. 2.

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FIG.1.

FIG.3.

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FIG.2.

SPECIFICATION

Coin discrimination apparatus

5 *FIELD OF THE INVENTION*

This invention relates to coin discrimination
apparatus and has particular but not exclusive
application to a multi-coin tester.
10
BACKGROUND TO THE INVENTION
In the prior art, for example the Model EM5
Electronic Multi-coin Acceptor manufactured
by Coin Controls Limited, of Oldham, Lancash-
15 ire, discrimination between different denomina-
tions of coin is achieved by means of an in-
ductive test. Coins under test pass along a
predetermined path between pairs of sensor
coils. Each pair of sensor coils is connected in
20 its own oscillator circuit. As the coin passes
between the coil pairs, the magnitude of the
oscillations in the coils is affected in depen-
dence upon the size and metallic character-
istics of the coin.
25 The present invention seeks to improve
upon this prior arrangement.

SUMMARY OF THE INVENTION
In accordance with the present invention
30 there is provided coin discrimination apparatus
comprising means defining a path for passage
of coins under test, sensor coil means for
forming an inductive coupling with coins under
test during their passage along the path, said
35 sensor coil means being connected in a reso-
nant circuit, oscillator means for energising the
resonant circuit, control means for controlling
the frequency of oscillation of the oscillator
means in such a manner that the resonant
40 circuit is maintained in resonance whilst a coin
under test is inductively coupled thereto, and
amplitude response means responsive to
changes in amplitude of an oscillatory signal
developed by the resonant circuit when the
45 coin under test passes the sensor coil means
and is inductively coupled thereto.
The impedance of the sensor coil means
consists of a "real" (resistive) and "imagi-
nary" (inductive) component. Other prior art
50 devices have concentrated on measurement of
the inductive component. However, in accor-
dance with the present invention, the ampli-
tude change of the oscillatory signal provides
a means to monitor the resistive component.
55 In accordance with the invention it has been
appreciated that this resistive component var-
ies, as a coin passes the sensor coil means,
by approximately twice as much as the induc-
tive component. Thus by means of the pre-
60 sent invention it is possible to maximise infor-
mation obtained from the coil, resulting in im-
proved. discrimination between coins and
against noise.
In accordance with the invention, the sensor
65 coil means may be connected in a parallel

capacitance/inductance resonant circuit. At the
resonant frequency, such parallel resonant cir-
cuits have the property of a purely resistive,
very high electrical impedance, the magnitude
70 of which is strongly influenced by the resistive
component of the sensor coil impedance. As
the coin passes the sensor coil means, the
apparatus is so arranged that the resonant cir-
cuit is maintained in resonance by changing
75 the frequency of the oscillator means. This is
preferably but not necessarily achieved by
means of a phase locked loop. The amplitude
of the oscillation developed across the reso-
nant circuit thus changes as the coin passes
80 the sensor coil. This signal is preferably de-
modulated and digitised in order to provide
signals which may be further processed to de-
termine the denomination and authenticity of
the sensed coin.
85 The digitised signals may be compared with
stored predetermined values representative of
true coins of different denominations. These
predetermined values may be stored in a pro-
grammable memory. The programmable mem-
90 ory may comprise an electronically erasable .
programmable read only memory hereinafter
referred to as an EEPROM. The EEPROM may
be programmed under the control of an exter-
nal programming unit which may be connected
95 selectively to the circuit, or may be prepro-
grammed in the factory.
Preferably, the sensor coil means includes a
plurality of sensor coils for forming an induc-
tive coupling with coins travelling along the
100 path, wherein a first of said coils is disposed
to one side of the path, a second of the said
coils is disposed to another side of the path
and the third of the said coils is so arranged
that the path passes through the windings
105 thereof.
Preferably, but not necessarily, the diameter
of the first coil is greater than the largest coin
to be tested by the apparatus.
The preferred coil arrangement used in the
110 present invention permits an improved discrim-
ination between coins of different diameter
and different metallic content.
As is explained in more detail in relation to
the embodiment hereafter, the magnetic fields
115 due to the third coil may be arranged orthogo-
nal to the field of the first two coils and
thereby measurements of the interaction of
the coin and the magnetic field due to the
coils are influenced by different characteristics
120 of the coin. In addition, for the third coil, the
response of the device has a complex depen-
dency on the frequency of oscillation of the
coil. With the first two coils, however the
coins show a simple trend of improving coin
125 discrimination with frequency. Thus, the coil
arrangement provided in the present invention
extracts information about the coin under test
which is a function both of the mechanical
geometry of the coin and the coils, and of the
130 field frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more
fully understood an embodiment thereof will
5 now be described in detail with reference to
the accompanying drawings wherein:

Figure 1 is a schematic view of a multi-coin
acceptor in accordance with the invention;

Figure 2 is a schematic circuit diagram for
10 discrimination circuitry connected to the sen-
sor coils shown in Figure 1; and

Figure 3 is a graph showing how the fre-
quency and amplitude of the oscillation pro-
duced on line 15 in Figure 1 deviates with
15 time.

Referring to Figure 1, the apparatus consists
of a coin path 1 along which the coins under
test roll edge-wise past first second and third
sensor coils 2, 3, 4. The coils are connected
20 to discrimination circuitry which is shown in
more detail in Figure 2. Broadly stated, if the
coin detected by the sensor coils is identified
as a true coin, a solenoid operated accept
gate 5 (Figure 1) is opened to allow the coin
25 to pass along path 1a down an accept chute
6. If the coin is identified by the circuitry to
have non-acceptable characteristics, e.g. a
counterfeit coin, the gate 5 is not opened and
the coin passes along path 1b to a reject
30 chute 7.

Provided in the accept chute 6 is a further
coil 8 which is energised in such a manner as
to detect the presence of acceptable coins.
This provides a positive check to the circuitry
35 of Figure 2 that credit has been accumulated.

In accordance with the invention, the sensor
coil arrangement 2, 3, 4 is selected to maxim-
ise discrimination between different coin de-
nominations and counterfeit coins. The first
40 coil 2 is disposed to one side of the coin
passageway such that its axis extends ortho-
gonally of the plane of the major face of the
coins as they pass the coil. The diameter of
the coil 2 is arranged to be generally but not
45 always larger than the maximum diameter of
coins that can pass down the passageway 1.
The second coil, 3, is disposed to the oppo-
site side of the coin passage way in the same
orientation as coil 2, but mechanically offset
50 above the floor (not shown) of the coin pass-
ageway such that only the upper parts of the
coin under test occludes it, in comparison
with coil 2 in which all the coin under test
occludes the coil. The third coil 4 is arranged
55 to wrap around the passageway such that the
coil axis is parallel to the length of the pass-
ageway. The three coils are energised at dif-
ferent frequencies F1, F2, F3, where typically,
F1 is 100 KHz, F2 equals 160 KHz and F3 is
60 100 KHz. This frequency arrangement permits
an improved discrimination between coin de-
nominations and counterfeit coins for the cur-
rent British coin set and counterfeit coin
(known as slugs). Of course other frequencies
65 may be necessary for other coin sets and

other uses of the device.

As shown in Figure 2, the coils 2, 3, 4, and
8 are each connected in a respective parallel
resonant circuit 10 to 13 containing capacitors
70 C1 to C4 and resistive temperature compen-
sating components R1 to R4. Each of the re-
sonant circuits 10 to 13 has its own natural
resonant frequency when no coins are in prox-
imity to the coils 2, 3, 4. Each of the reso-
75 nant circuits 10 to 13 is driven via a phase
locked loop at its own natural resonant fre-
quency by means of a voltage controlled oscil-
lator VCO which produces an oscillatory drive
signal on line 14. The resonant circuits 10 to
80 13 are sequentially connected in a feed-back
path to operational amplifier A1 via a multi-
plexer M1. The output of the multiplexer M1
on output line 15 is inverted by amplifier A2
and the resulting signal is compared in a
85 phase comparator PS1 with the output of the
voltage controlled oscillator VCO on line 14.
The output of the phase comparator PS1
comprises a control voltage on line 16 which
is used to control the frequency of the voltage
90 controlled oscillator VCO. The phase locked
loop maintains a 180° phase difference across
the amplifier A1, which is the required condi-
tion to maintain the selected resonant circuit
at its natural resonant frequency.
95 The multiplexer M1 is controlled by a micro-
processor MPU to switch sequentially the re-
sonant circuits 10 to 13 into the feed-back
path of amplifier A1, so as to scan the sensor
coils 2, 3, 4, 8 repetetively.
100 Thus, in use, in the absence of a coin, each
of the resonant circuits 10 to 13 will produce
sequentially on line 15 an output at a respec-
tive substantially constant frequency and am-
plitude, determined by the parameters of the
105 resonant circuit concerned. However, consider-
ing the case for example of resonant circuit
10, when a coin rolls past the coil 2, an in-
ductive coupling is formed between the coil 2
and the coin such that the impedance pre-
110 sented by the coil to the resonant circuit is
modified. Consequently both the frequency
and amplitude of the oscillation produced on
line 15 deviates with time substantially as
shown in Figure 3. The change in impedance
115 occurs by virtue of skin effect type eddy cur-
rents being induced by the coil in the coin.
The magnitude of the frequency and amplitude
deviations are dependent upon the relative
sizes of the coil and the coin, the coin dia-
120 meter and thickness, the metal from which the
coin is made and the surface pattern em-
bossed on the coin. Thus, as the coin passes
the coil 2, there is transitory deviation of the
natural resonant frequency for the resonant
125 circuit 10. In accordance with the invention,
the phase comparator PS1, the inverting am-
plifier A2 and voltage controlled oscillator VCO
operate as a phase locked loop to maintain
the drive frequency on line 14 at the resonant
130 frequency for the circuit 10. As a result, the

output from the resonant circuit on line 15, as
the coin passes the coil 2, deviates mainly in
accordance with the change in resistive com-
ponent of the sensing coil impedance. This
5 amplitude deviation is used as a parameter
indicative of the size, metallic content and the
embossed pattern of the coin.

The oscillatory signal on line 15 is demodu-
lated by a demodulator DM1 and digitised by
10 an analogue to digital converter circuit ADC.
The analogue to digital converter operates re-
petitively so as to sample the signal on line
15 and store in microprocessor MPU signals
indicative of the peak deviation of amplitude
15 as the coin passes the coil 2.

The microprocessor MPU then switches the
multiplexer M1 so that the process is repeated
for the coils 3 and 4 sequentially as the coin
passes the coils.
20 The resonant circuit 13 is utilised to ensure
that the coin, if accepted, passes to the ac-
cept chute 6.

It has been found that for a coin of a parti-
cular denomination, a substantially unique set
25 of amplitude deviations produced by the circu-
its 10, 11, 12, characterise the coin denomi-
nation. The device may thus be used as a
multi-coin tester and sets of digital values
which characterise these amplitude deviations
30 for respecitve different coin denominations are
stored in an EEPROM 17 to be compared by
the microprocessor MPU with the values pro-
duced by the analogue to digital converter
ADC for an actual coin under test. If the mi-
35 croprocessor determines the presence of an
acceptable coin, it provides an output on line
18 to open the solenoid operated accept gate
5.

Also the microprocessor may produce on
40 line or lines 19 an output indicative of accep-
tance of a coin of a particular denomination,
for further data processing.

Further, an output may be provided on line
20 to operate a coin sorter for discriminating
45 between coins of different denominations de-
tected by the device.

The EEPROM 17 may be programmed in the
factory with predetermined set of values
representative of acceptable coins. Alterna-
50 tively, the EEPROM may be programmed in
the field by means of an additional external
plug-in, microprocessor based unit (not
shown) which connects to the data input of
microprocessor MPU so as to override its nor-
55 mal operation and permit loading or modifica-
tion of stored values in the EEPROM 17. The
values to be stored for the EEPROM 17 may
be produced by means of test coins to be fed
through the coin passageway past the coils 2
60 to 4, which are sensed by the coils during an
initial setting up operation.

CLAIMS
1. Coin discrimination apparatus comprising
65 means defining a path for passage of coins

under test, sensor coil means for forming an
inductive coupling with coins under test during
their passage along the path, said sensor coil
means being connected in a resonant circuit,
70 oscillator means for energising the resonant
circuit, control means for controlling the fre-
quency of oscillation of the oscillator means in
such a manner that the resonant circuit is
maintained in resonance whilst a coin under
75 test is inductively coupled thereto, and ampli-
tude response means responsive to changes
in amplitude of an oscillatory signal developed
by the resonant circuit when the coin under
test passes the sensor coil means and is in-
80 ductively coupled thereto.

2. Apparatus according to claim 1 wherein
the sensor coil means is connected in parallel
with a capacitor in said resonant circuit, and
said control means includes a phase locked
85 loop.

3. Apparatus according to claim 1 or 2
wherein said oscillator means comprises a vol-
tage controlled oscillator, and said control
means includes a phase comparator arranged
90 to make a comparison of the phase of a sig-
nal from the resonant circuit with the phase of
the output of the oscillator and to control the
frequency of the oscillator in dependence upon
said comparison.
95 4. Apparatus according to any preceding
claim wherein the resonant circuit is connected
in a feedback path between an input and out-
put of an amplifier, said control means being
arranged to tend to maintain a 180° phase
100 difference between the input and the output of
the amplifier.

5. Apparatus according to any preceding
claim incuding demodulator means for demo-
dulating said oscillatory signal, and analogue
105 to digital converter means for successively
producing digitised sample value of the demo-
dulated signal.

6. Apparatus according to claim 5 including
microprocessor means responsive to said digi-
110 tised sample value to determine the peak devi-
ation of amplitude of the demodulated signal
as a coin passes the sensor coil means.

7. Apparatus according to claim 6 wherein
said microprocessor means is arranged to
115 compare said peak deviation with a predeter-
mined value thereof to provide signal indica-
tive of acceptability or otherwise of the coin.

8. Apparatus according to claim 7 wherein
the microprocessor means is arranged to com-
120 pare said peak deviation with a plurality of
predetermined values thereof to provide a sig-
nal indicative of coin denomination.

9. Apparatus according to claim 8 wherein
said predetermined values are programmed
125 into a programmable memory.

10. Apparatus according to any preceding
claim wherein said sensor coil means includes
a plurality of sensor coils each connected in a
respective said resonant circuit, and including
130 multiplexer means for connecting said reso-

nant circuit sequentially to said amplitude re-
sponse means.

11. Apparatus according to any preceding
claim wherein said sensor coil means includes
5 a plurality of sensor coils for forming an in-
ductive coupling with coins travelling along the
path, wherein a first of the coils is disposed
to one side of the path, a second of the coils
is disposed to another side of the path, and
10 the third of the coils is so arranged that the
path passes through the windings thereof.

12. Apparatus according to claim 11
wherein the diamter of the first coil is greater
than that of the largest coin to be tested by
15 the apparatus.

13. Apparatus for discriminating between
coins of different characteristics, comprising
means defining a path for passage of coins
under test, a plurality of sensor coils for form-
20 ing an inductive coupling with coins travelling
along the path, means for energising the coils,
and means responsive to said inductive cou-
pling to discriminate between coins under test
of different characteristics, the improvement
25 comprising that a first of said coils is dis-
posed on one side of the path, a second of
the coils is disposed on another side of the
path, and the third coil has circular windings
through which the path passes.

30 14. Coin discrimination apparatus substan-
tially as hereinbefore described with reference
to the accompanying drawings.

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